Studies of Gd and Tb radiation in 6.x spectral region

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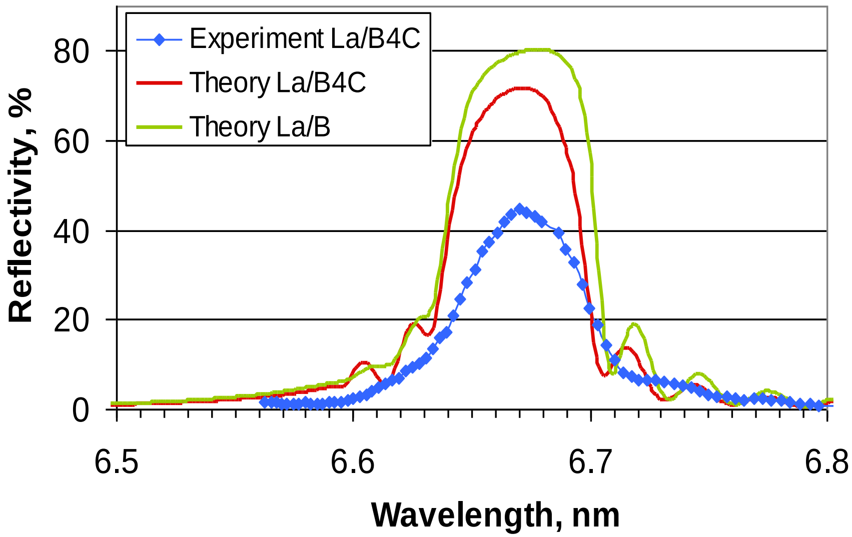
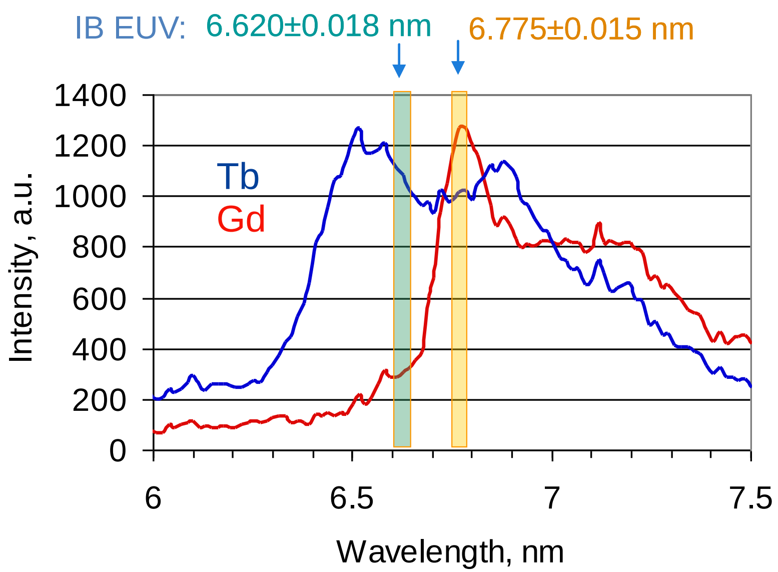
Agenda

- Directions for source optimization
- LPP with Nd laser at 1.06 μ
- LPP with CO_2 laser at 10.6 μ
- Laser assisted DPP on Gd and Tb
- Summary & conclusion

Directions for source optimization

- Max achieved reflectivity R=50% with La/B_4C (Rigaku, Maui, June 2011)
- Theoretical maximum for La/B_4C R~73% @6.62 nm,
- Theoretical maximum for La/B R~82% @6.65 nm
- Summary bandwidth for 10 La/B MLM is 0.6 % (vs 2% for Mo/Si MLMs @ 13.5 nm)

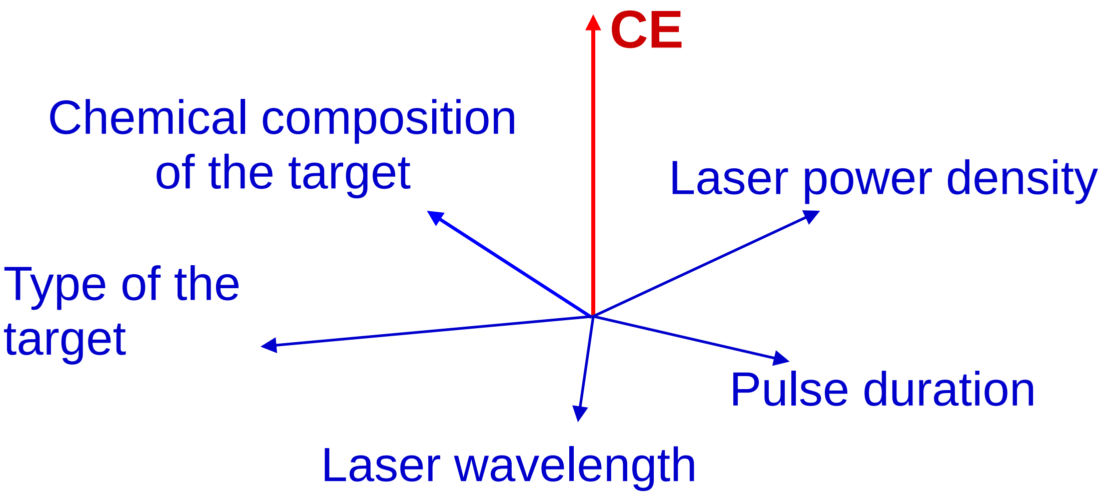




Directions for source optimization

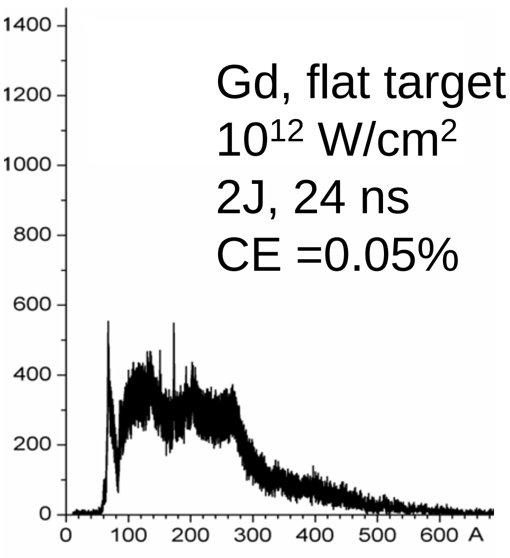
REGULATING HANDLES

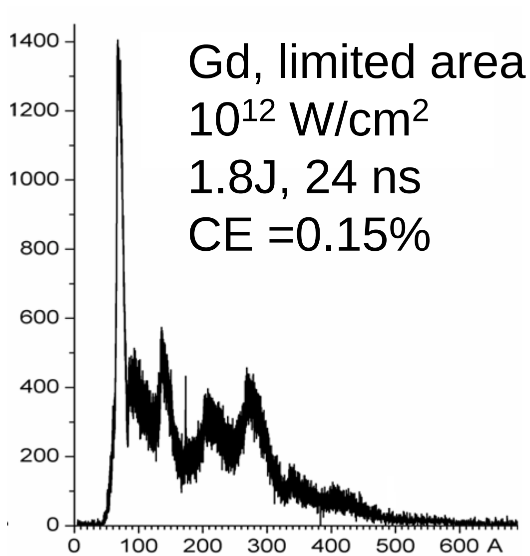
PHYSICAL ISSUES

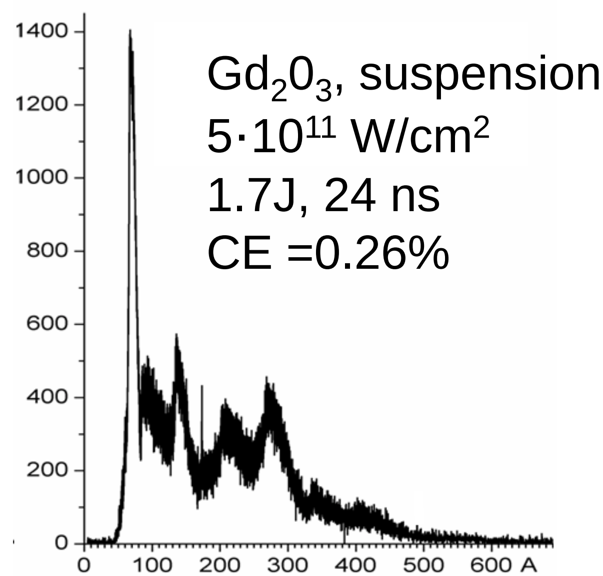


Plasma dynamics
Ion composition
Plasma shape
Effects of opacity
Laser absorption

Experiments on LPP with Nd:YAG laser



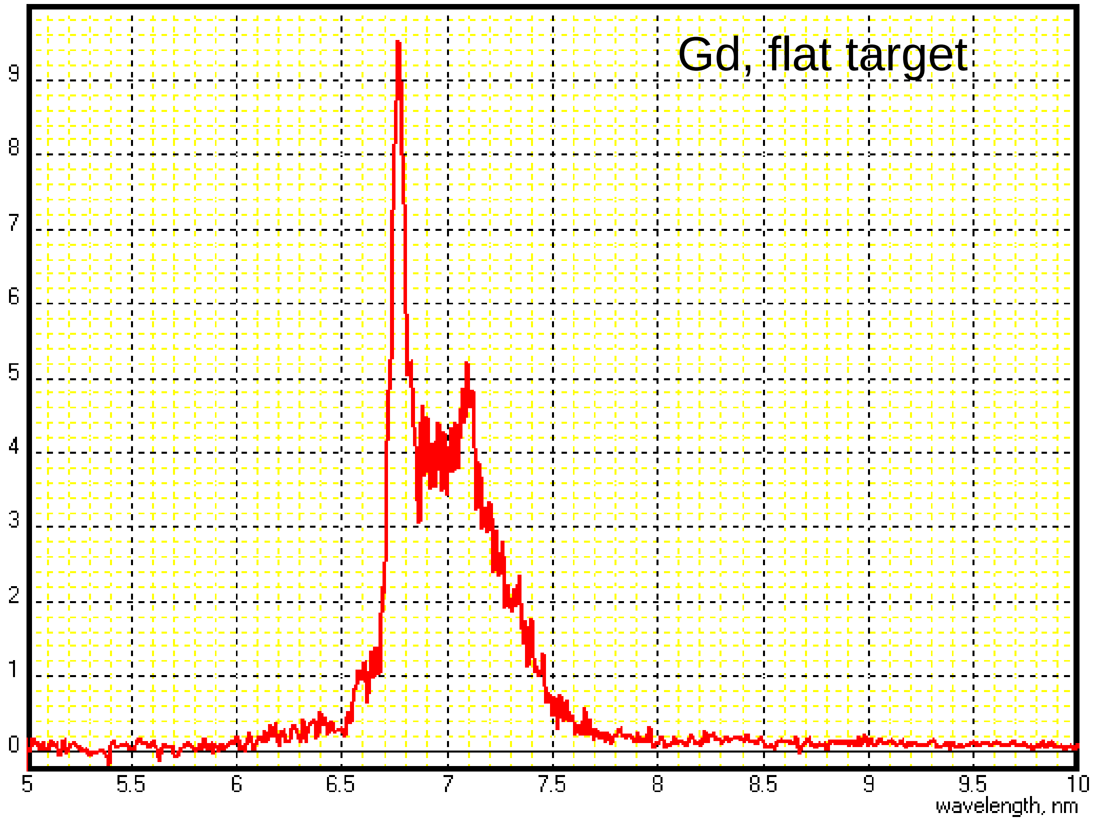




Elimination of the effects of plasma opacity (self absorption) leads to increase CE

Decreasing of laser pulse direction from 20ns to 2ns results in increase CE up to 1%

Experiments on LPP with CO_2 laser



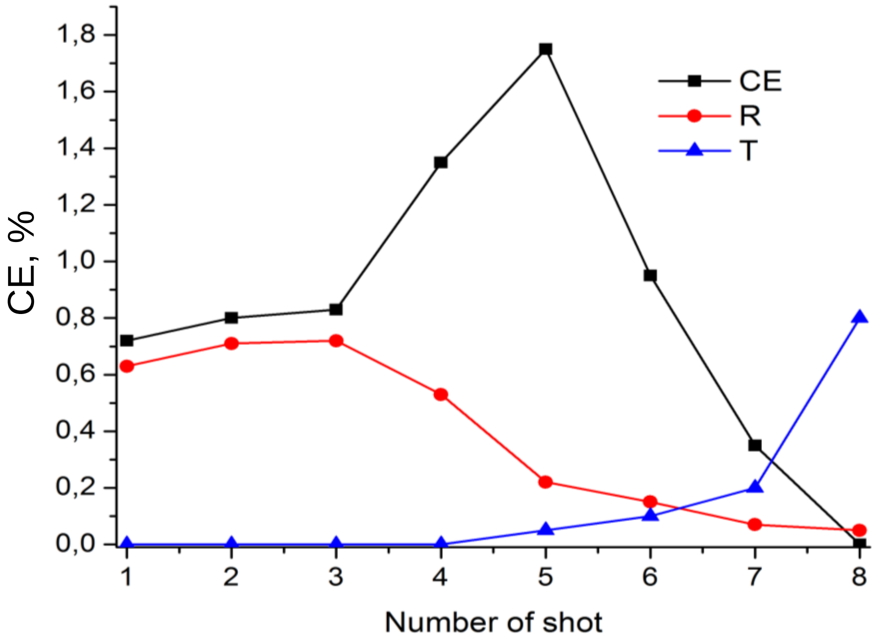
Typical spectrum of CO_2 laser produced Gd plasma

- Plasma is optically transparent
- CE increases with laser power density on the target
- CE measured at $3 \cdot 10^{10}$ W/cm^2 is about 1% as maximum
- Strong reflection of laser radiation is observed and it increase with increasing of laser power density

Absorption coefficient decreases with temperature

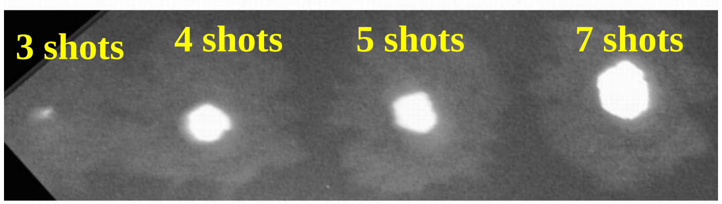
$$k_{abs}^{las} = \frac{16\pi Z n_e^2 e^6 \ln \Lambda(\nu)}{3c\nu^2(2\pi m_e k_B T_e)^{3/2}(1 - \nu_p^2/\nu^2)^{1/2}}$$

Experiments on LPP with CO_2 laser

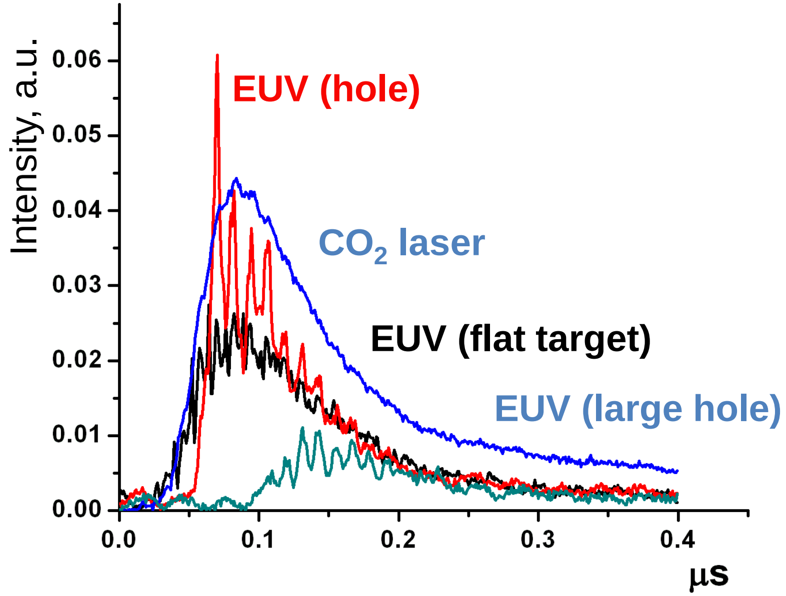


Target – Gd foil 80 μ thick

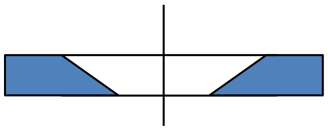
Laser energy 600 mJ
Laser spot dia. 300 μ
Pulse duration 100 ns
Pow. density ~10^{10} W/cm^2



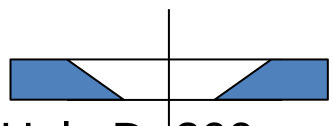
View of holes in 80 μ Gd foil after defined number of laser shots



Modeling of evolution of the electron density on perforated target



Hole D=150 μ
Laser spot 200μ



Hole D=200 μ
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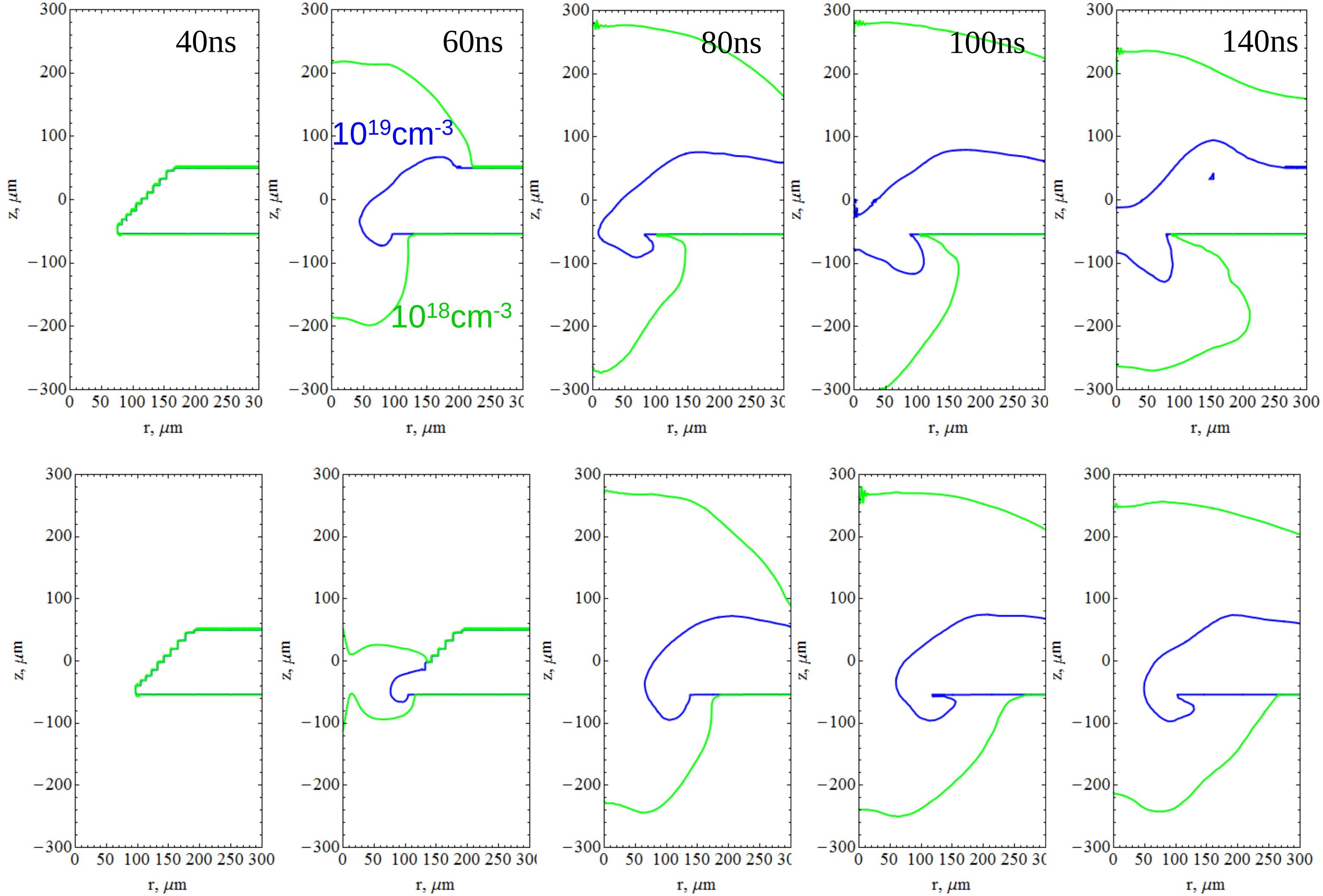
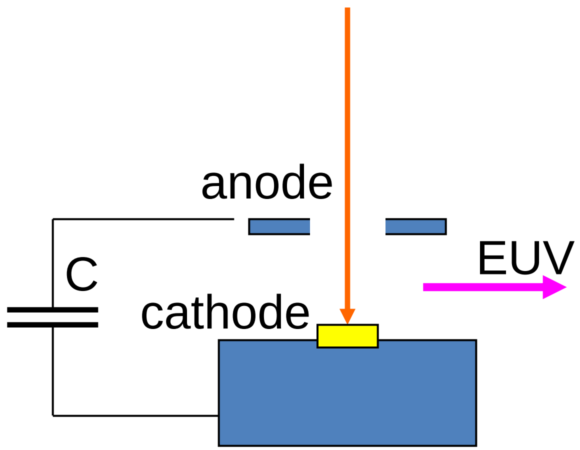


150ns

DPP based on Gd and Tb



Discharge circuit:

A-C = 4 mm

L = 9 nH

C = 0.4 uF

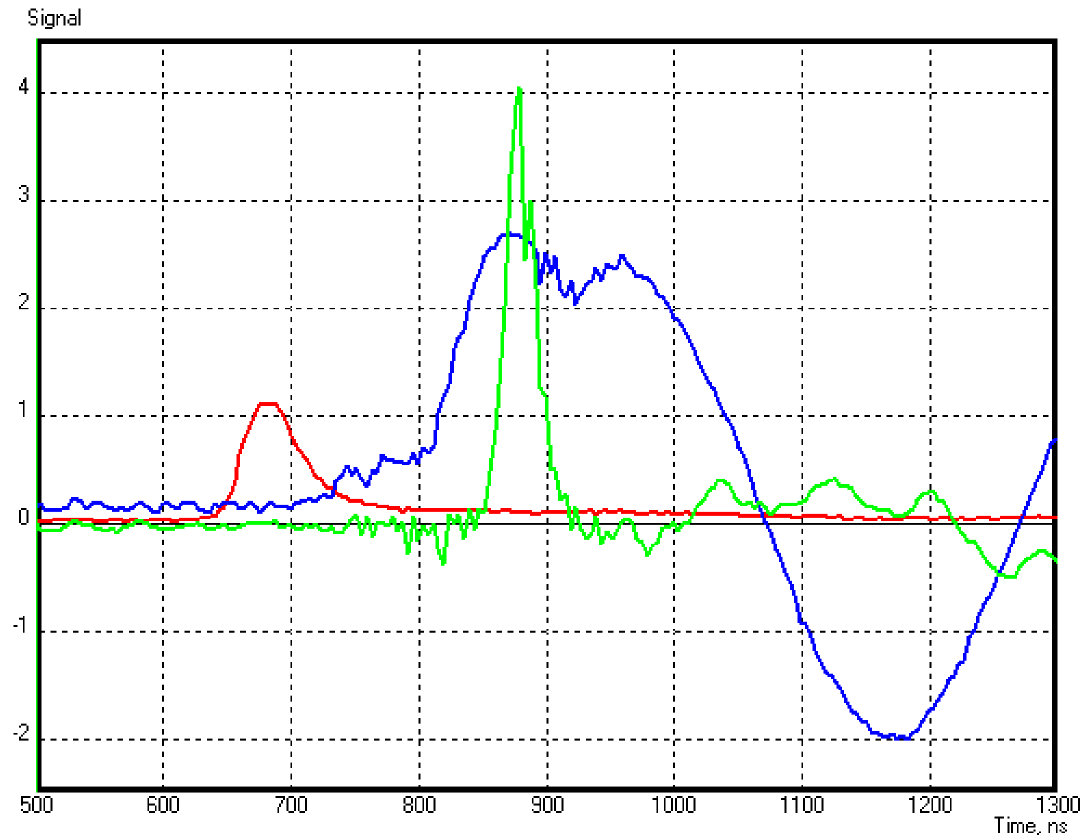
U = 5 – 7 kV

E = 5 – 10 J

Nd:YAG laser:

E = 25 mJ

t = 40 ns



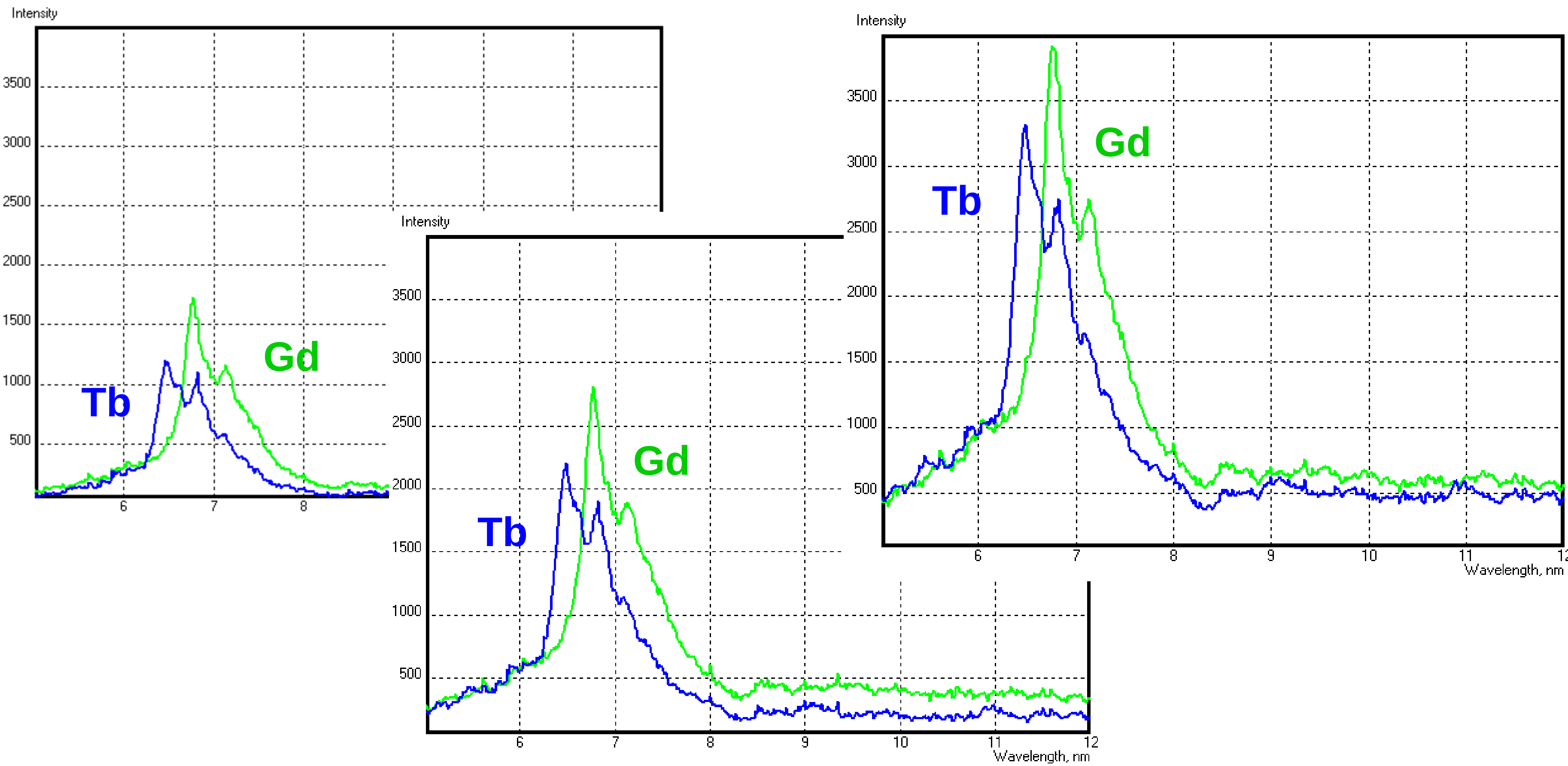
View of discharge scenario

RED – triggering laser

BLUE – discharge current

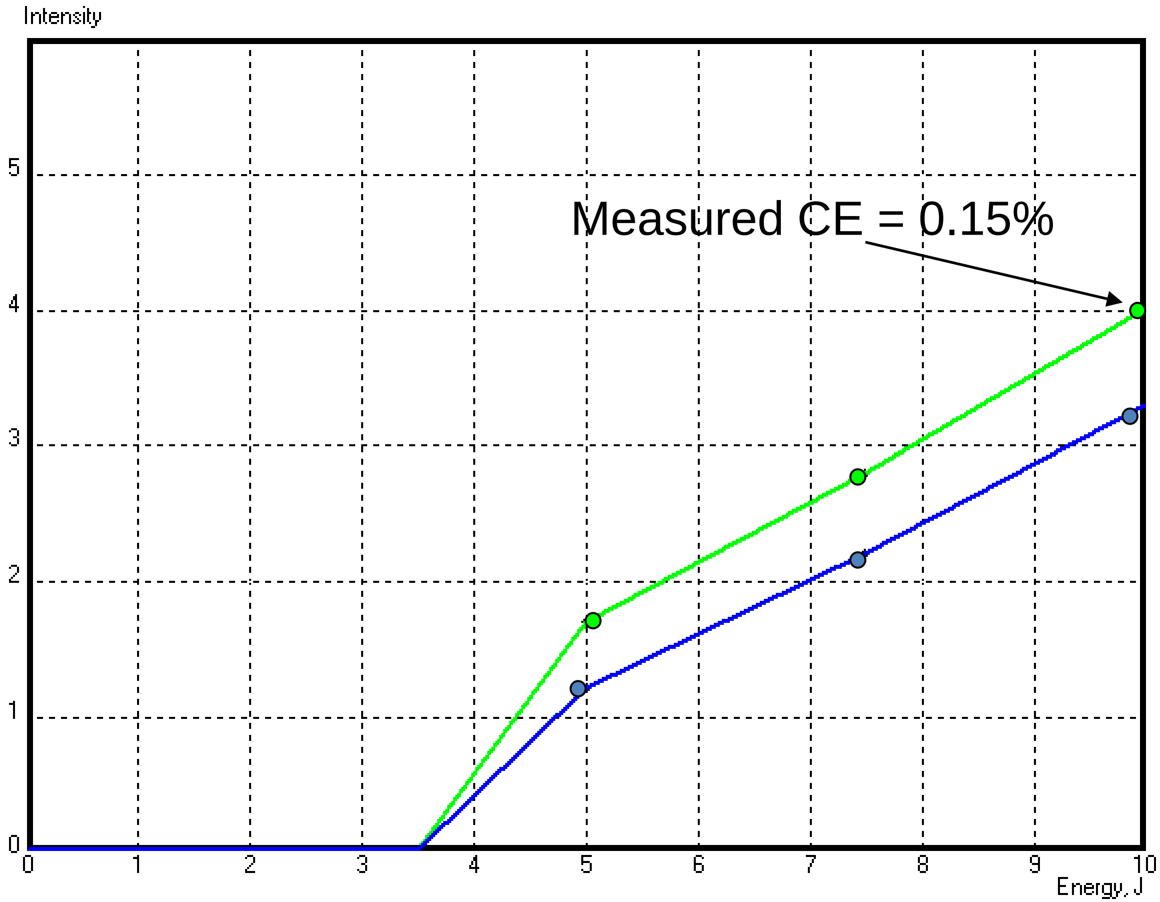
GREEN – in-band EUV

DPP based on Gd and Tb



View of Gd and Tb spectra at different energies of discharge

DPP based on Gd and Tb

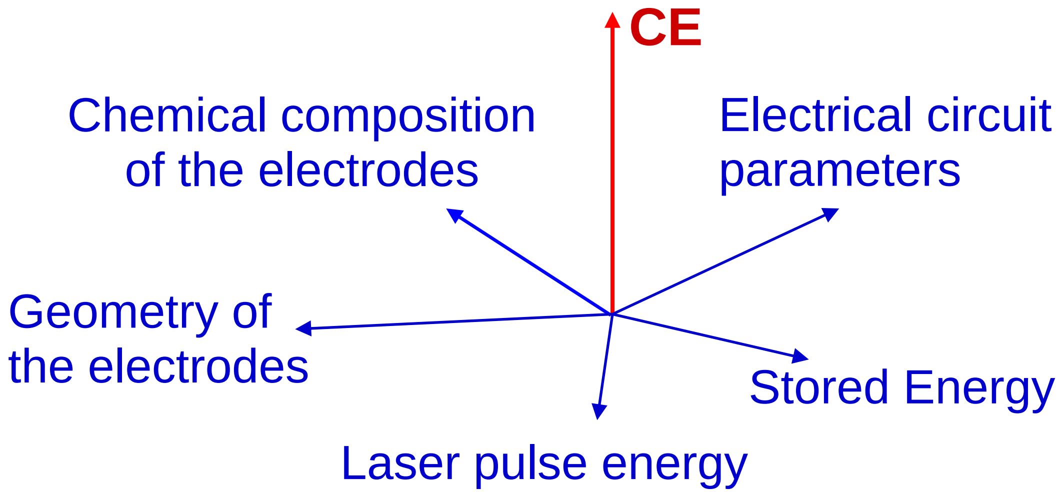


Gd at 6.78 nm

Tb at 6,49 nm

Dependence of in-band yield for Gd and Tb plasmas on electrical discharge energy

DPP based on Gd and Tb



LOT OF SPACE FOR OPTIMIZATION

Conclusions

• Energy spectra and conversion efficiency coefficient (CE) in 0.5 % band around 6.775 nm for Gd plasmas produced with radiation of CO_2 (10.6μm) and Nd (1.06μm) lasers have been measured.

• In order to optimization coupling of laser excitation with emitting plasma different types of targets was tested.

•CE of about 1 % measured with a CO2 laser on solid bulk Gd targets, the highest CE about 2% was achieved on Gd foil perforated targets with a room for further increase.

•Experiments on laser assisted DPP with Gd and Tb have been started.

People contributed to the presentation

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KIAM: Vladimir Novikov,
Alexander Grushin

ASML: Vadim Banine,
Andrei Yakunin

Thank You for Your Attention